

EIC prospects for SIDIS and ΔG

Thomas Burton
BNL

RHIC and AGS Users' Meeting 2010

Overview

- What do we currently know about spin?
- What do we need to learn & improve?
- How does an EIC allow us to do this?
 - ▶ ΔG
 - ▶ SIDIS - longitudinal & transverse spin

Spin of the nucleon

$$\frac{1}{2}\hbar = \left\langle P, \frac{1}{2} \left| J_{QCD}^z \right| P, \frac{1}{2} \right\rangle = \sum_q \frac{1}{2} S_q^z + S_g^z + \sum_q L_q^z + L_g^z$$

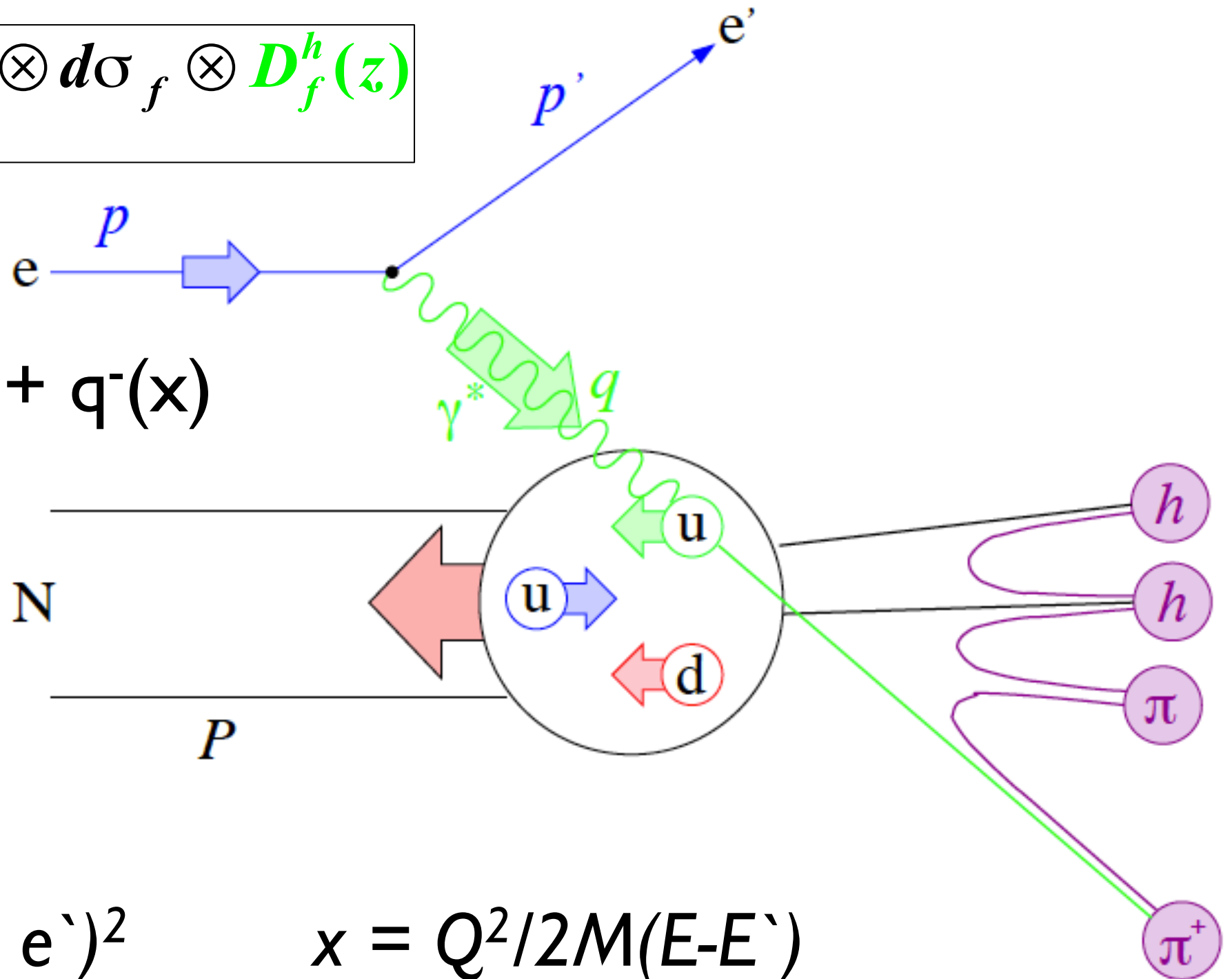
- Ultimate goal: disentangle quark, gluon and orbital contributions to nucleon spin
- Understand spin-dependent parton dynamics (Sivers, Boer-Mulders...).
- Many quantities/distributions are still poorly known.



Deep inelastic scattering

$$d\sigma^h(z) \sim \sum_f q_f(x) \otimes d\sigma_f \otimes D_f^h(z)$$

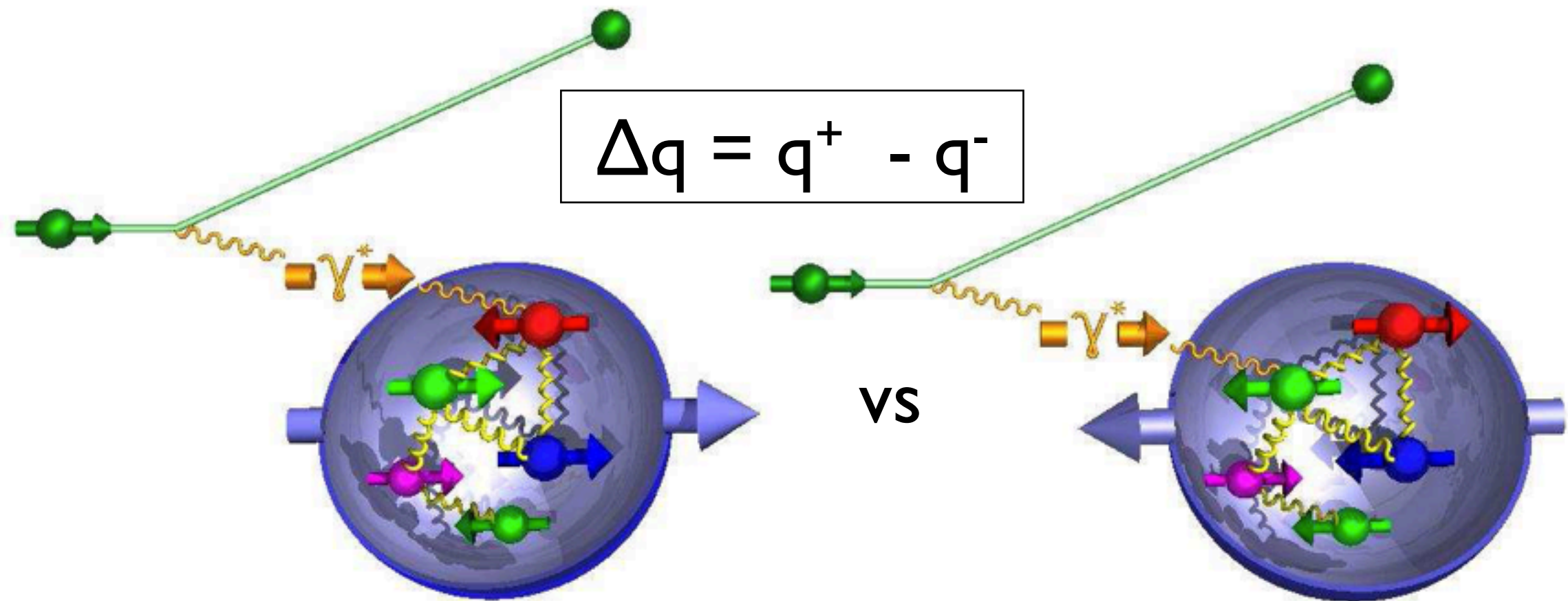
$$F_1(x) = \sum_q q^+(x) + q^-(x)$$



$$Q^2 = -q^2 = -(e - e')^2$$

$$x = Q^2 / 2M(E - E')$$

Longitudinal spin in DIS



Quark (spin $1/2$)
absorbs
photon (spin 1)
and flips helicity

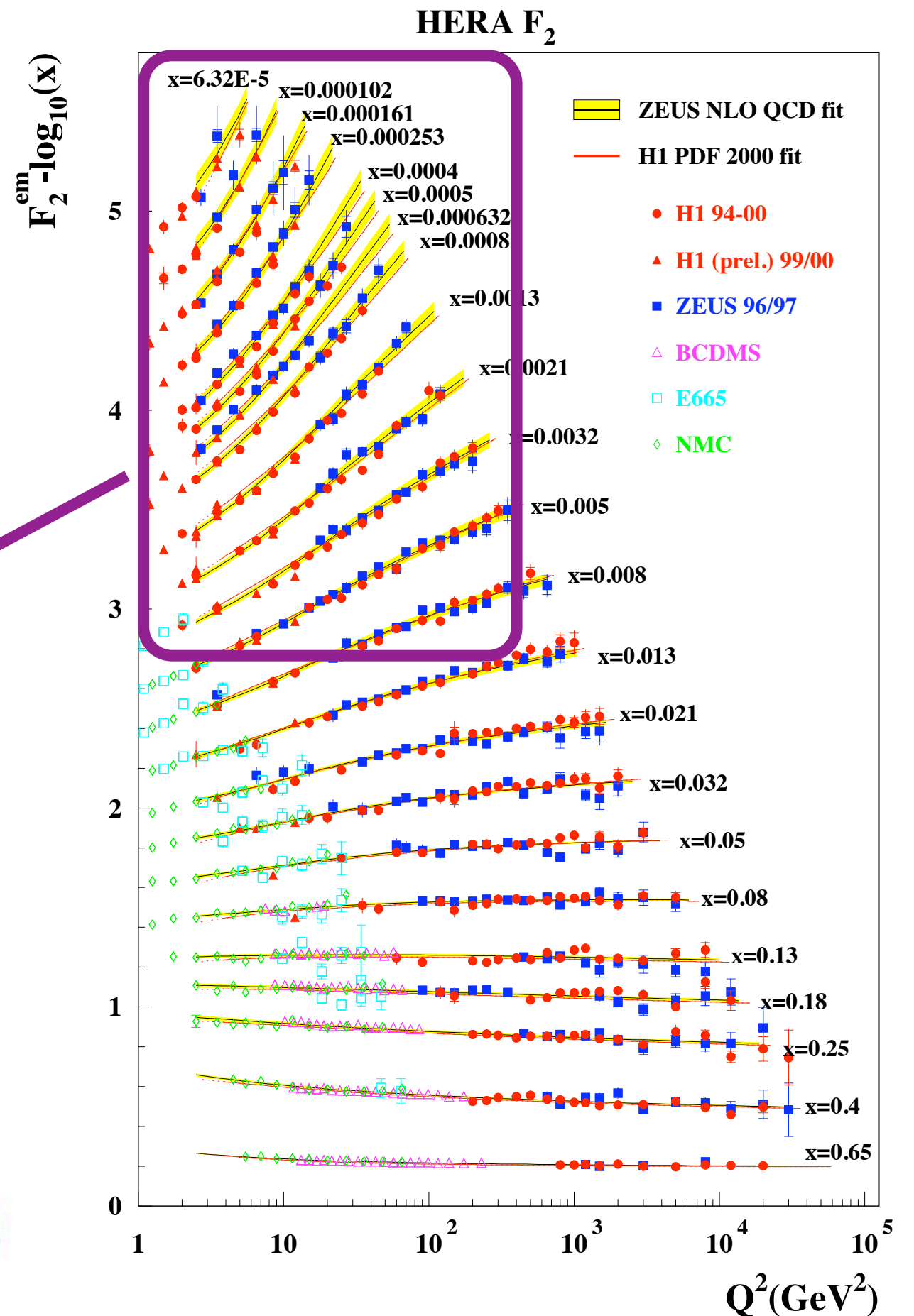
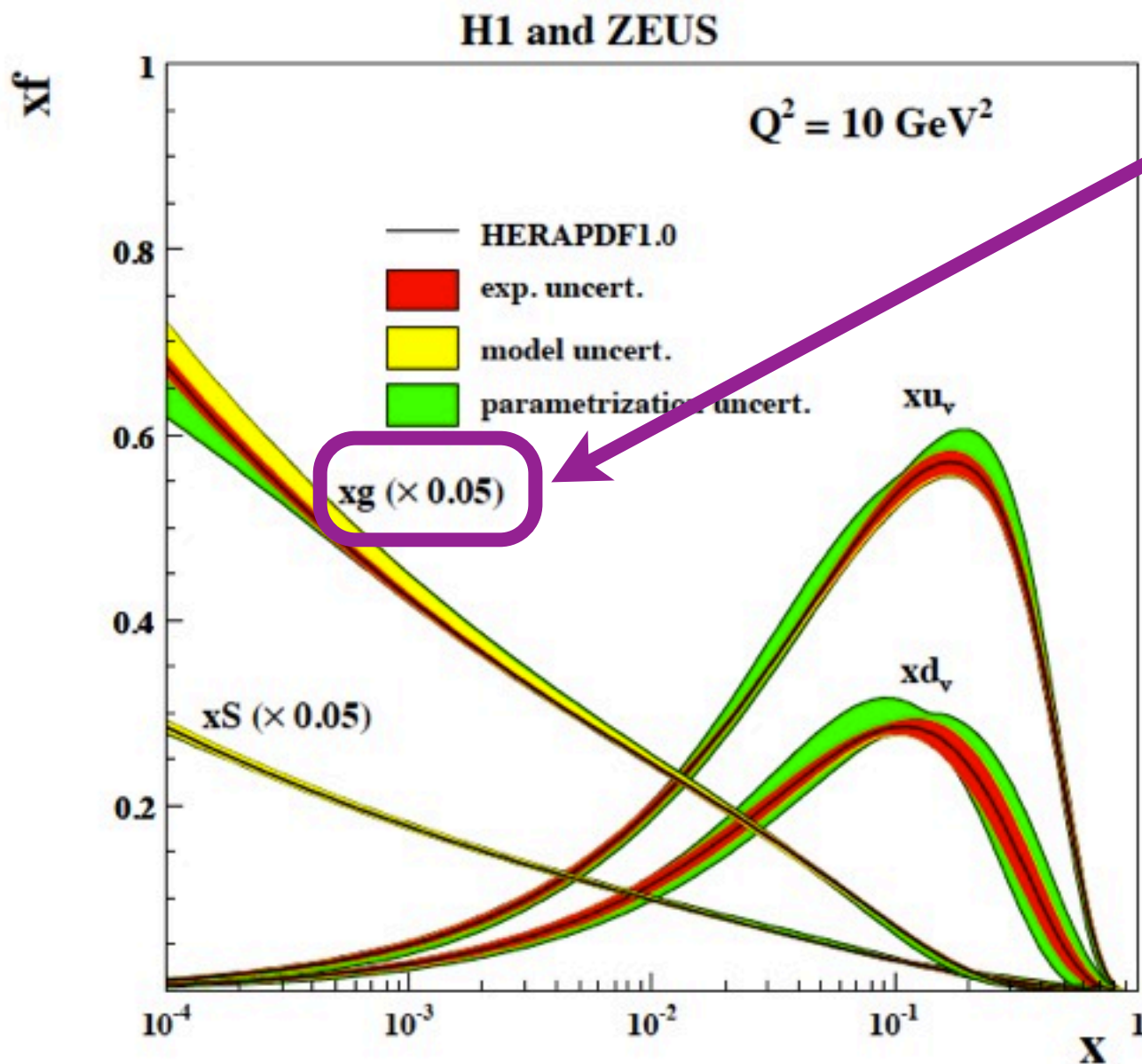
$$F_1(x) = \sum_q q^+(x) + q^-(x)$$

$$g_1(x) = \sum_q q^+(x) - q^-(x)$$

$$A_1 = g_1 / F_1$$

HERA

Scaling violations



DIS

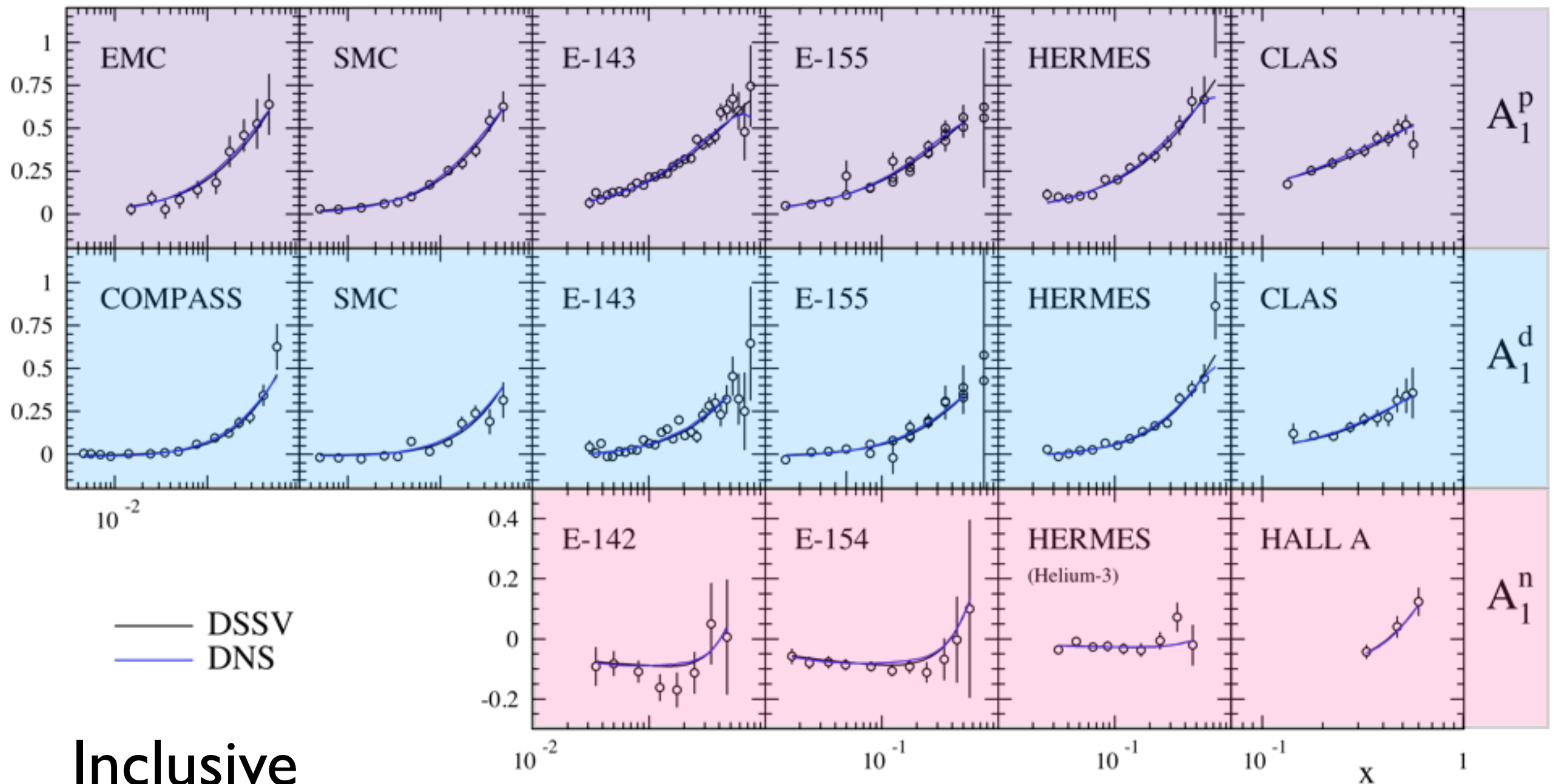
- Exquisite control of parton kinematics.
- Clean and precise determination of parton distributions
 - We would like the same precision for spin-dependent distributions
 - ➔ Detailed understanding of nucleon spin structure
- *Where do we currently stand with this aim?*

Gluon contribution to the nucleon helicity: ΔG

$$\frac{1}{2}h = \left\langle P, \frac{1}{2} \left| J_{QCD}^z \right| P, \frac{1}{2} \right\rangle = \sum_q \frac{1}{2} S_q^z + S_g^z + \sum_q L_q^z + L_g^z$$

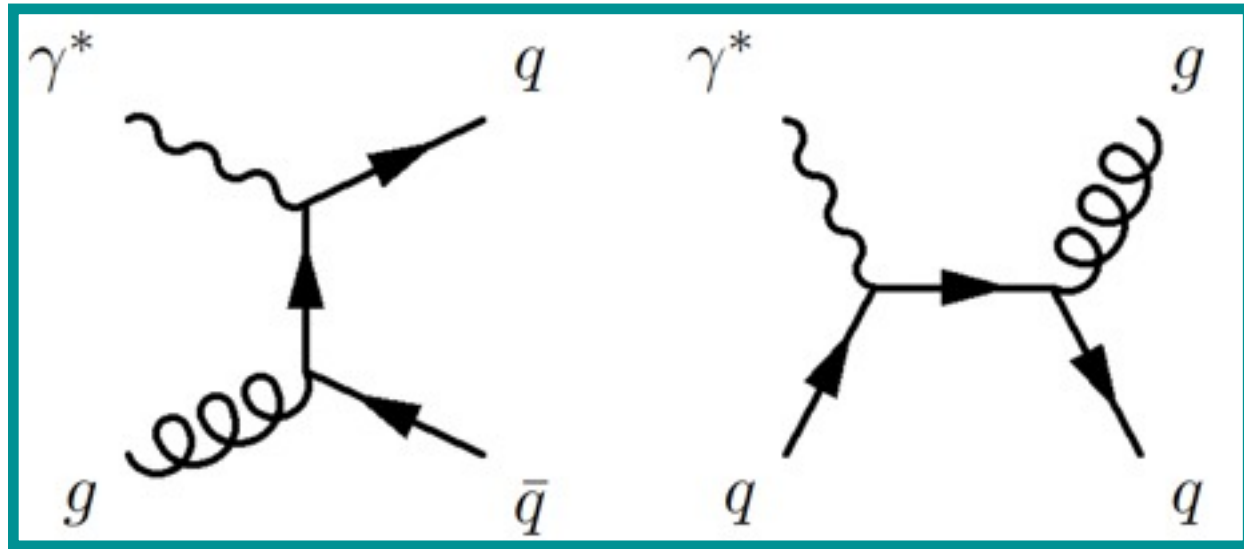
- $\Delta G = \int dx \Delta g(x)$
- $\Delta g = g^+ - g^-$

I) Inclusive DIS spin asymmetries

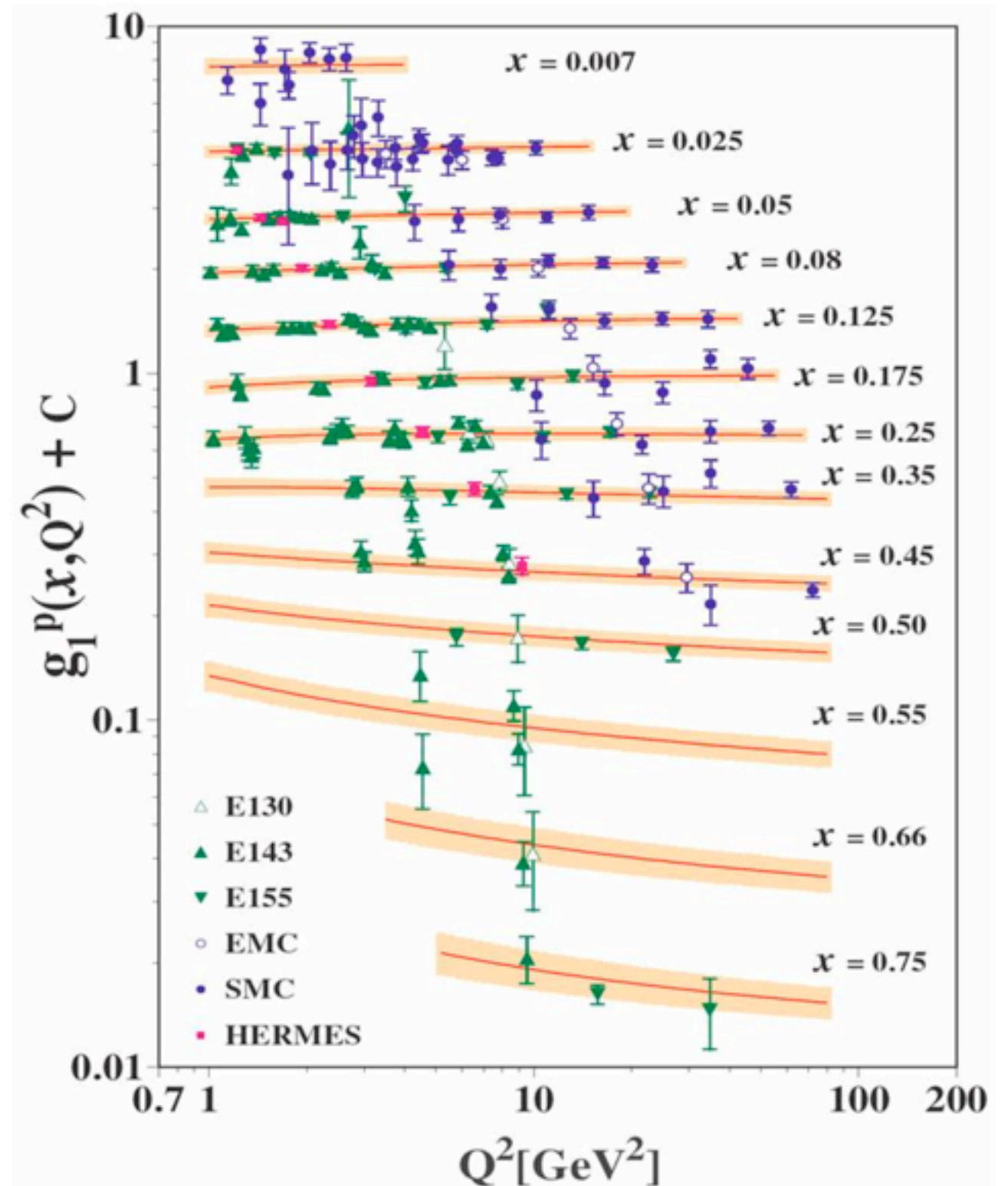


Inclusive
world data

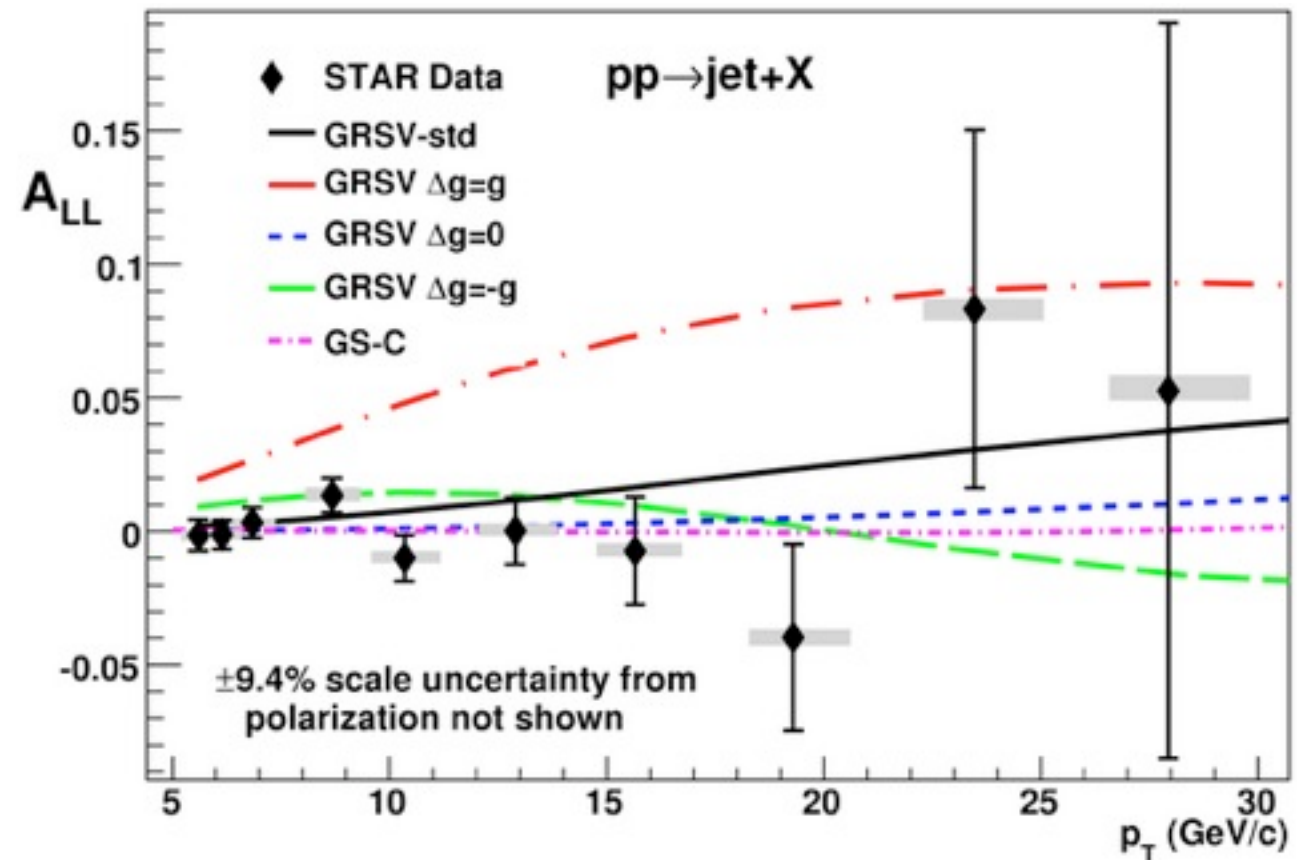
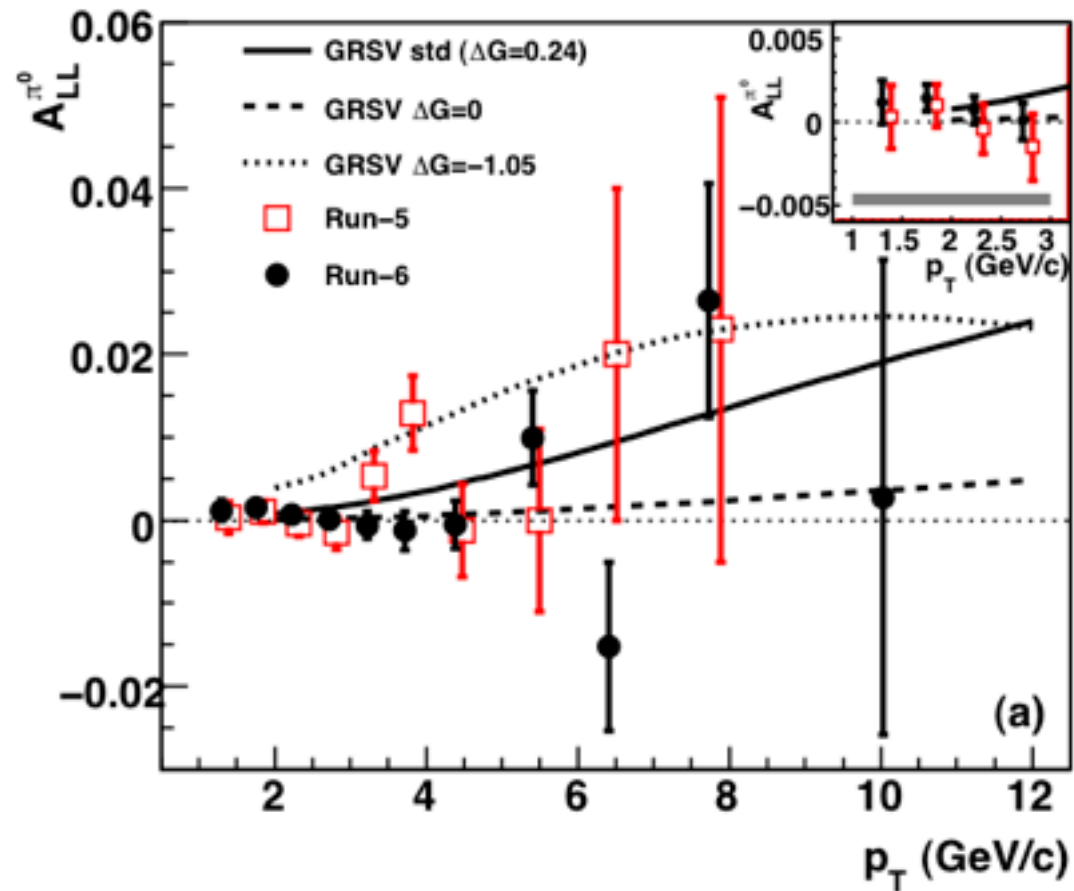
g_1 scaling violations



Scaling violations (Q^2 -dependence) give **indirect access** to the gluon distribution via DGLAP evolution.

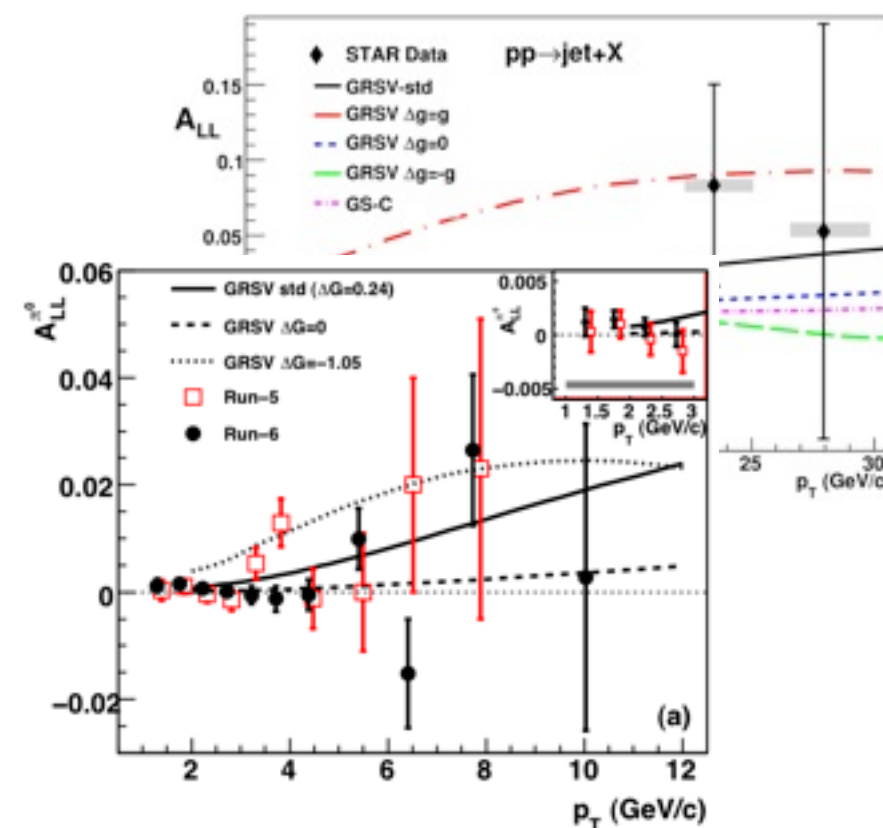
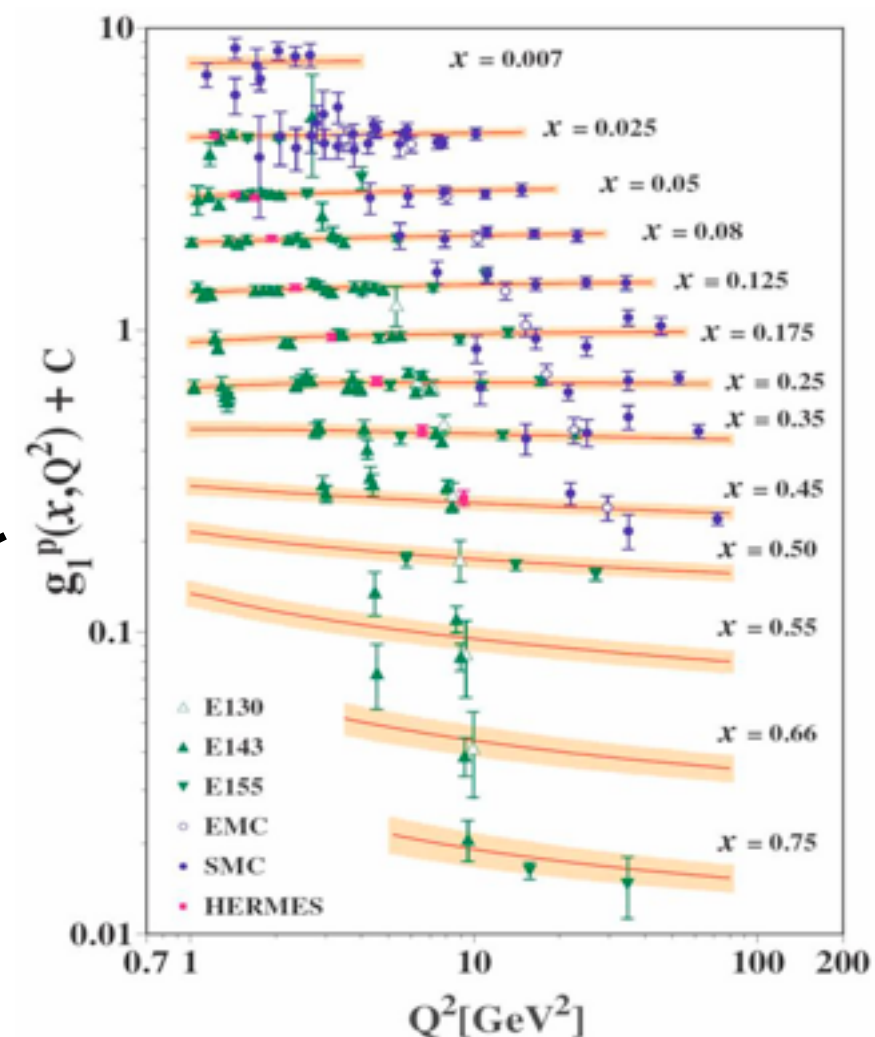
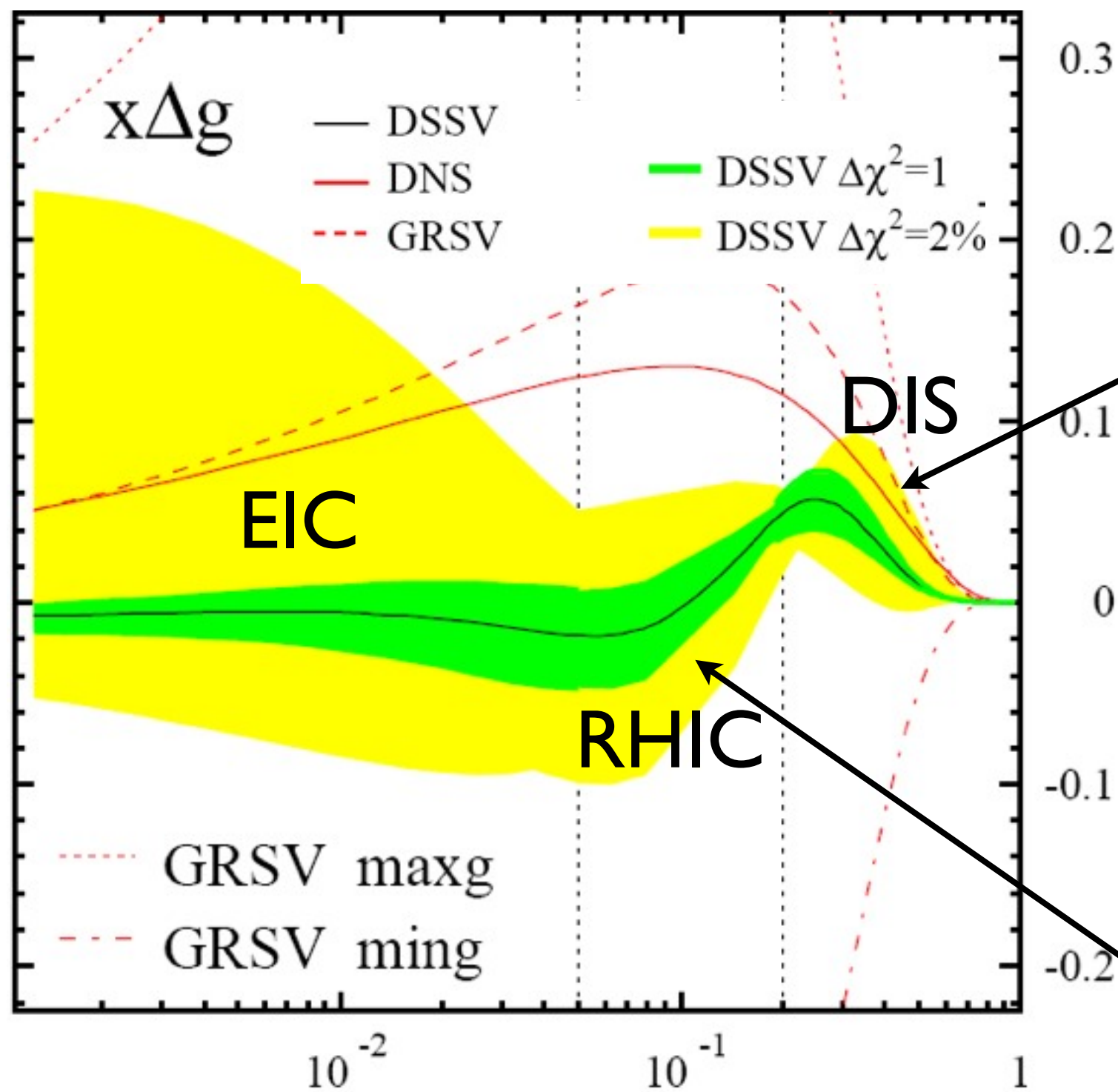


2) ΔG from $p + p$

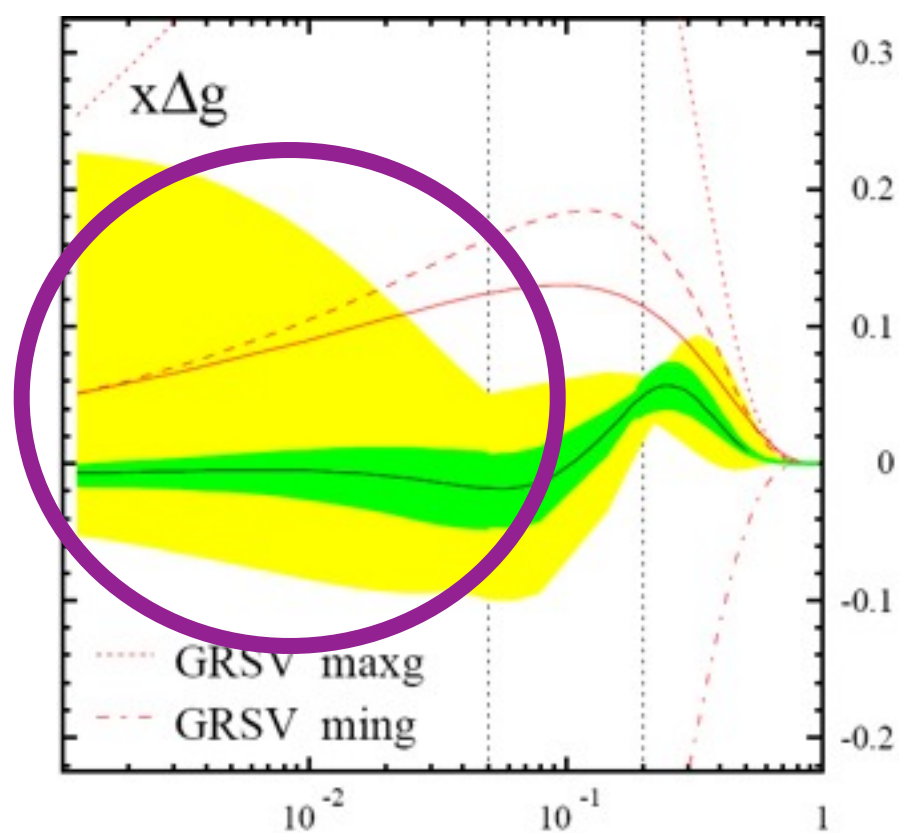


RHIC $p + p$ collisions at midrapidity **directly** involve gluons

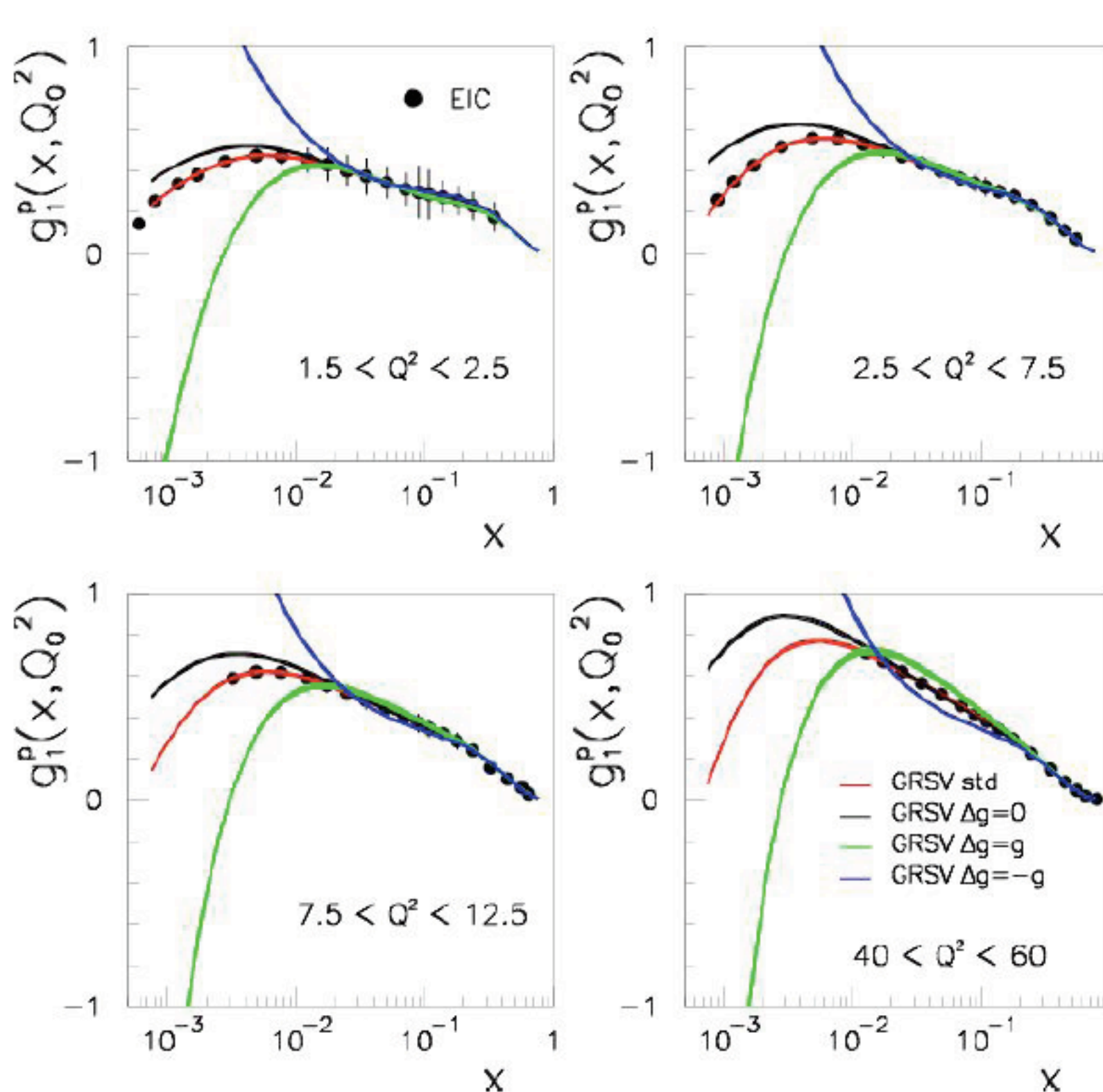
Rule out large ΔG for $0.05 < x < 0.2$



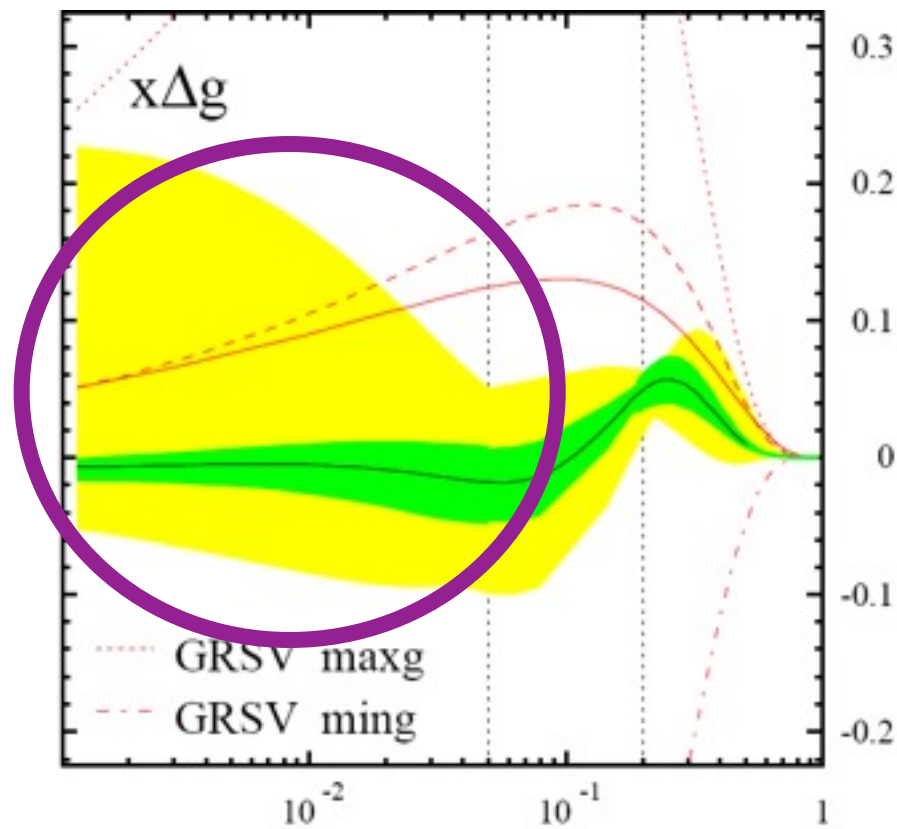
Small at currently accessible x
 $\Delta G = -0.084$



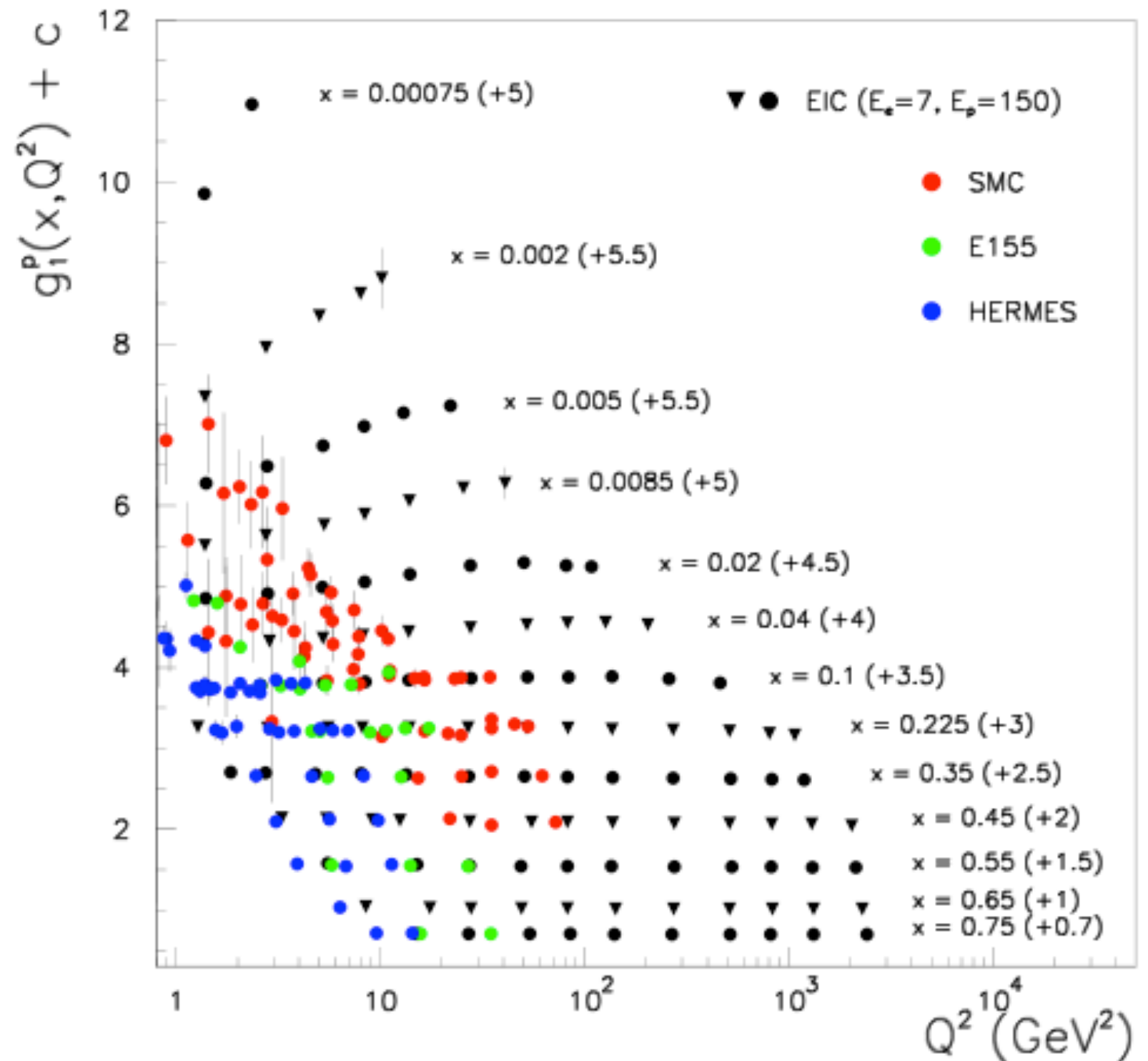
Access to ΔG at
small x where
uncertainties are
very large



5fb⁻¹ integrated luminosity



Access to ΔG at
small x where
uncertainties are
very large



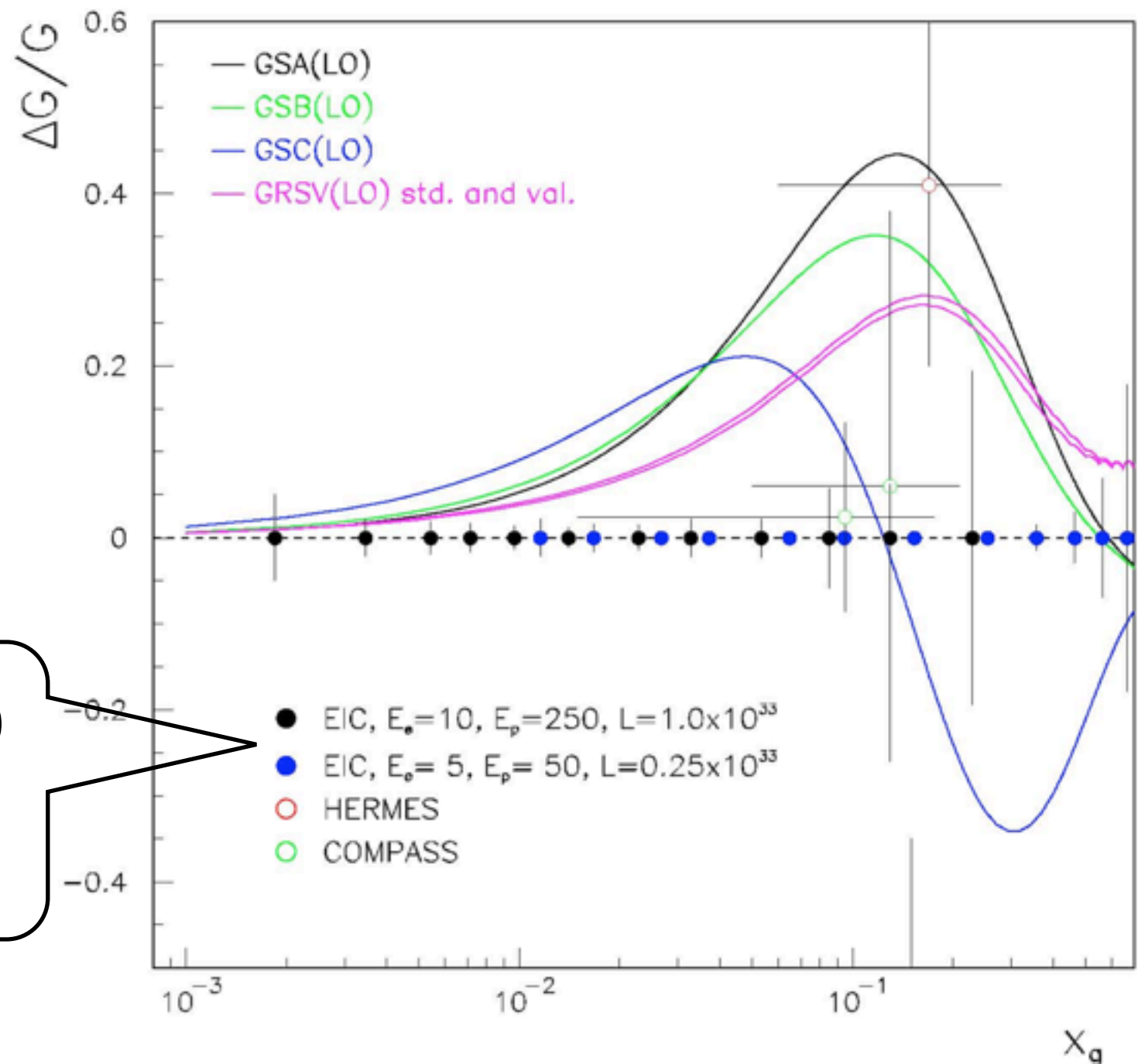
5fb⁻¹ integrated luminosity

ΔG via charm

- Measure charm production via $D^0 \rightarrow K^- \pi^+$
- High energy \rightarrow theoretically clean

10 fb⁻¹ at 10+250

2.5 fb⁻¹ at 5+50

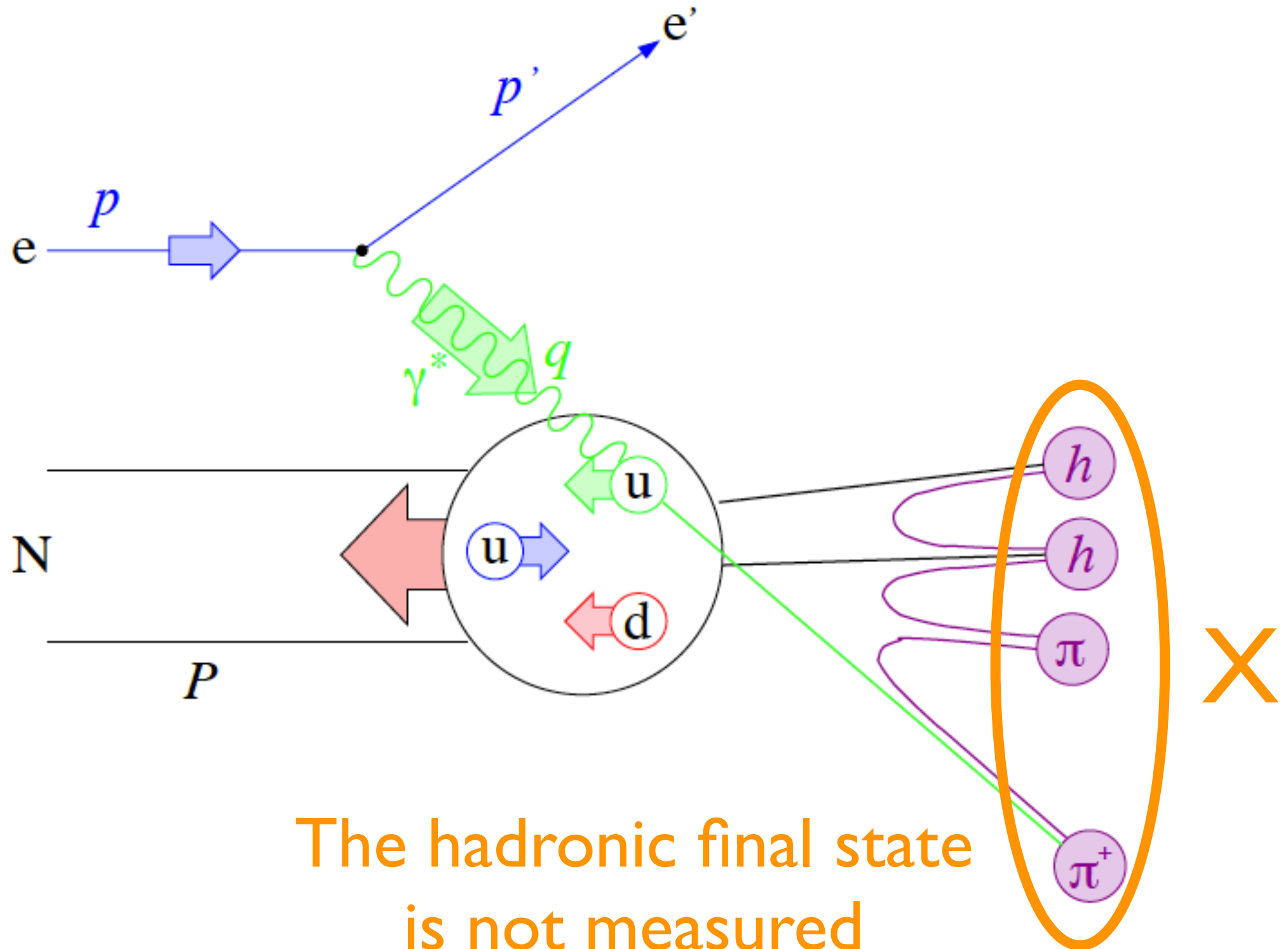


Gluon polarisation

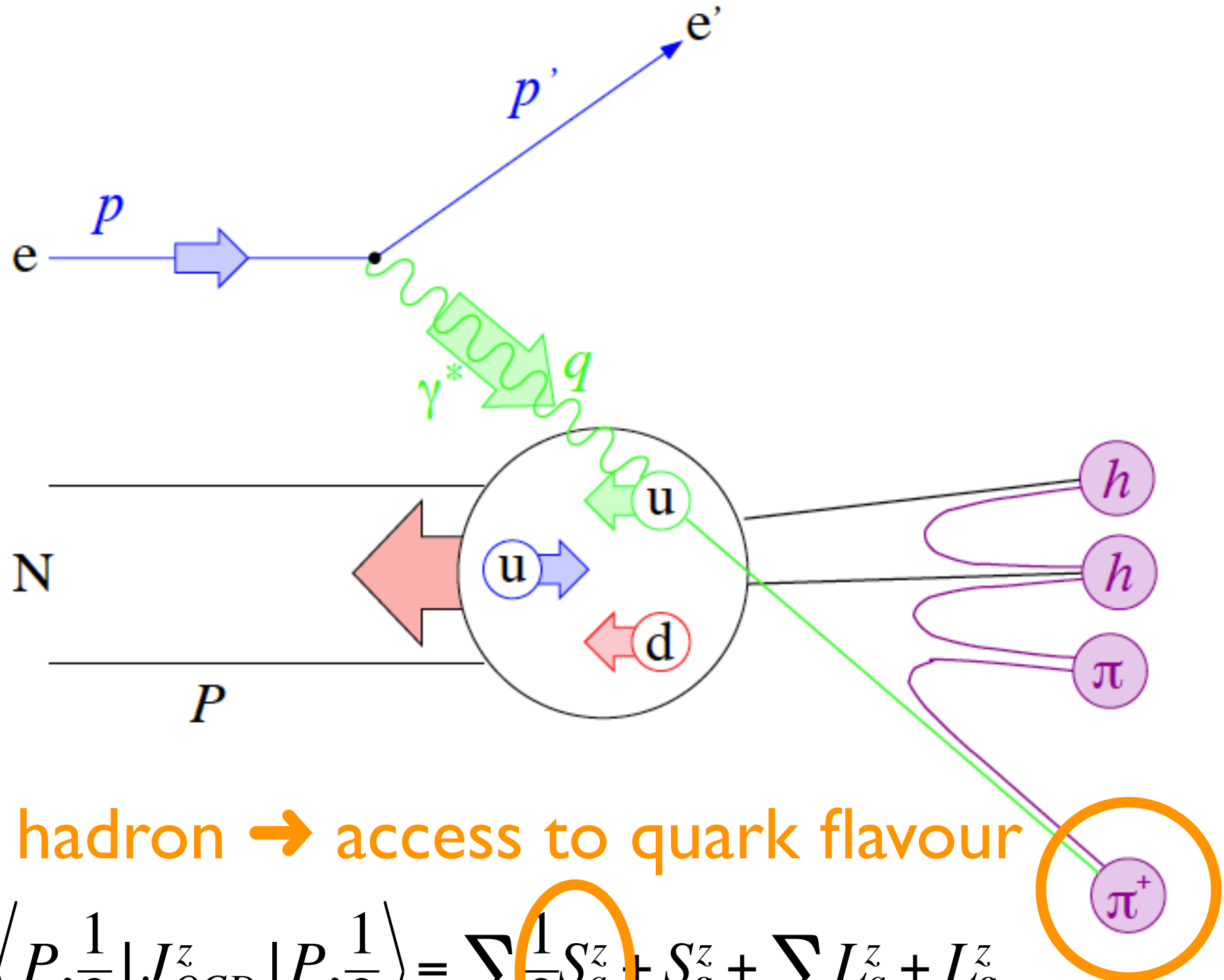
- EIC will provide precise g_1 to small x
- ➔ Determination of Δg at small x
- ➔ Reduced uncertainty on ΔG due to low- x extrapolation
- ➔ Precise test of the Bjorken sum rule

$$\int_0^1 dx (g_1^p(x, Q^2) - g_1^n(x, Q^2)) = 1/6 g_A (1 + O(\alpha_s) + O(1/Q^2))$$

inclusive DIS



Semi-inclusive DIS: SIDIS

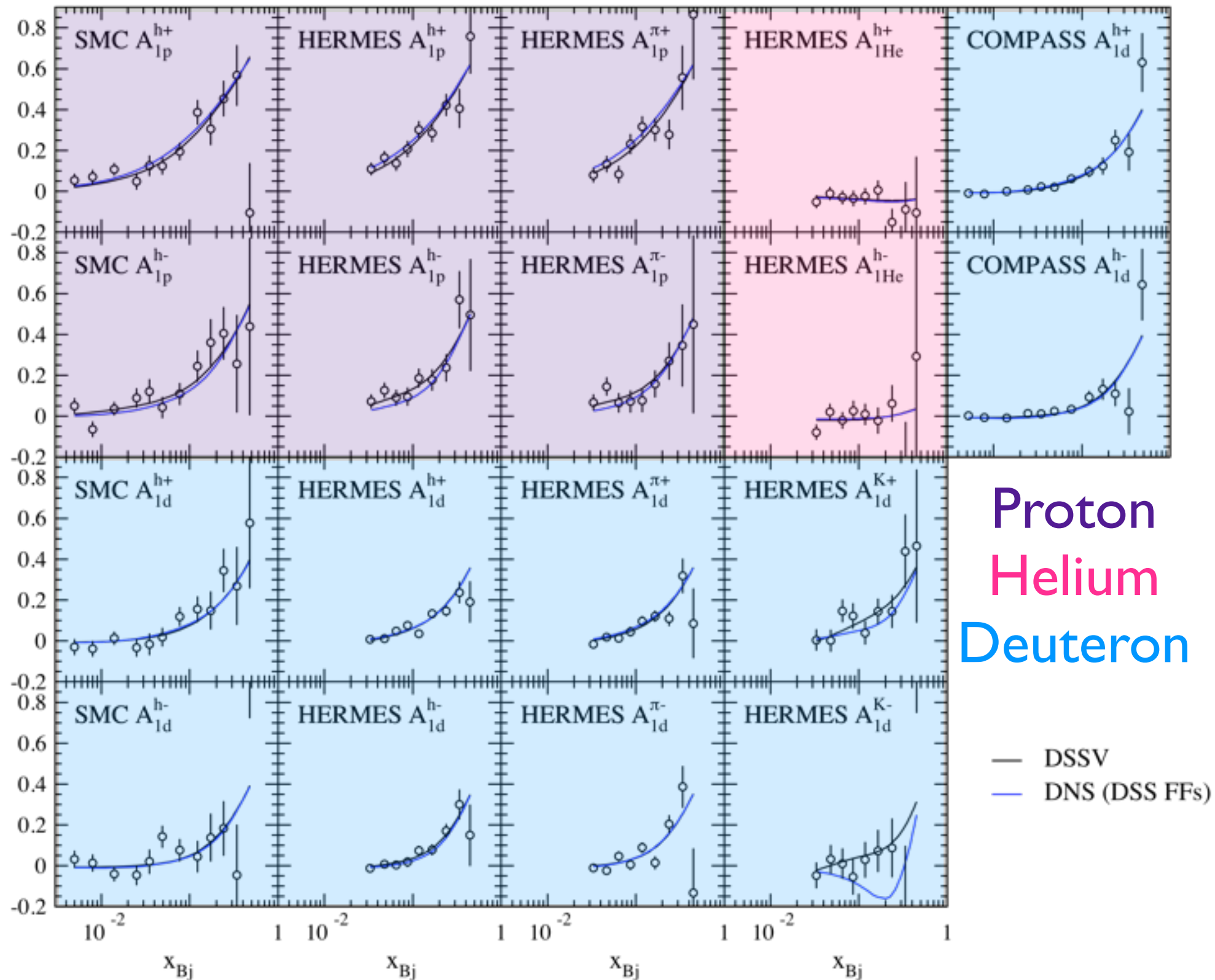


Tag a hadron → access to quark flavour

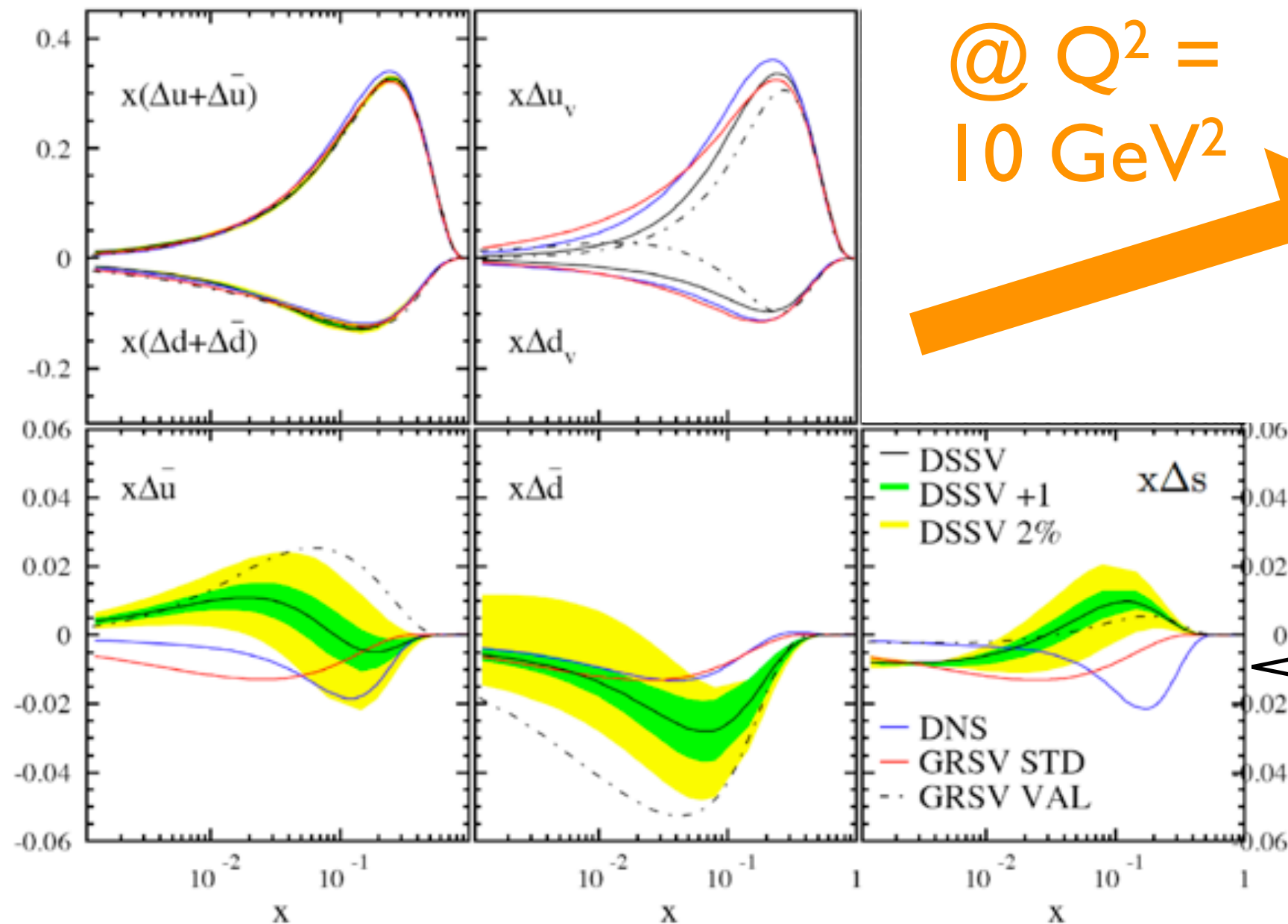
$$\frac{1}{2}h = \left\langle P, \frac{1}{2} \left| J_{QCD}^z \right| P, \frac{1}{2} \right\rangle = \sum_q \left(\frac{1}{2} S_q^z + S_g^z + \sum_q L_q^z + L_g^z \right)$$

Longitudinal spin

Semi-inclusive DIS asymmetries



Flavour-dependence



@ $Q^2 =$
10 GeV^2

$$\Delta u = 0.813$$

$$\Delta d = -0.459$$

$$\Delta \bar{u} = 0.036$$

$$\Delta \bar{d} = -0.115$$

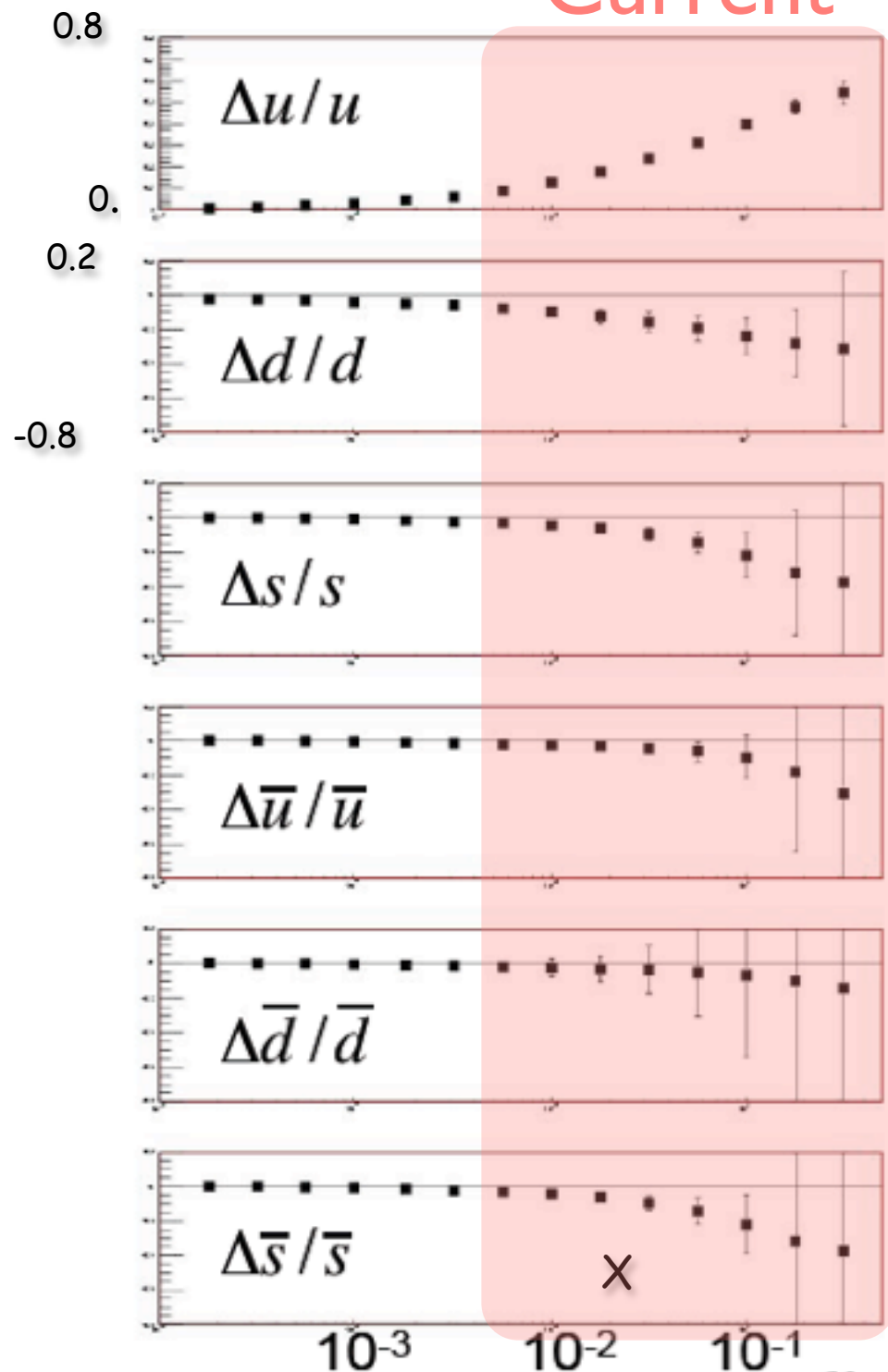
$$\Delta \bar{s} = -0.057$$

$$\Delta \Sigma = 0.242$$

Sea
uncertainties
remain large

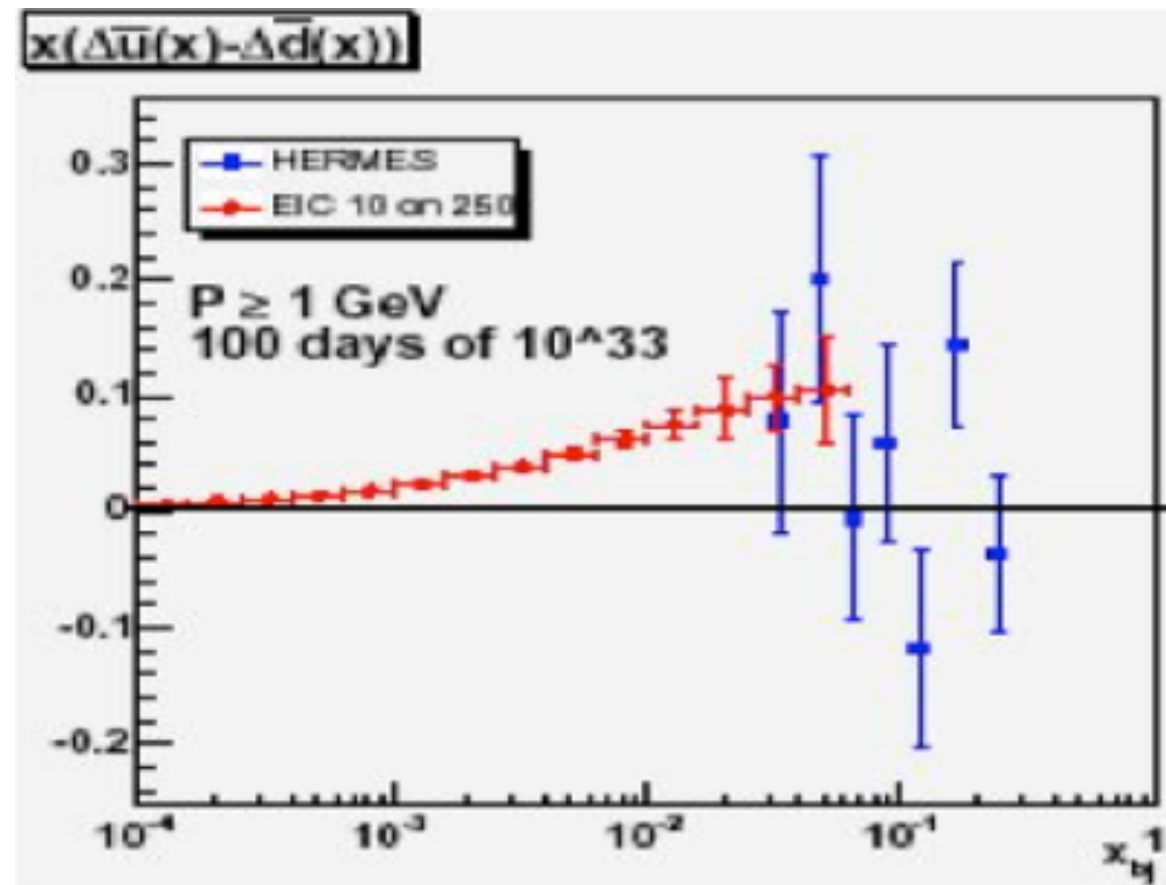
Flavour-dependence

Current



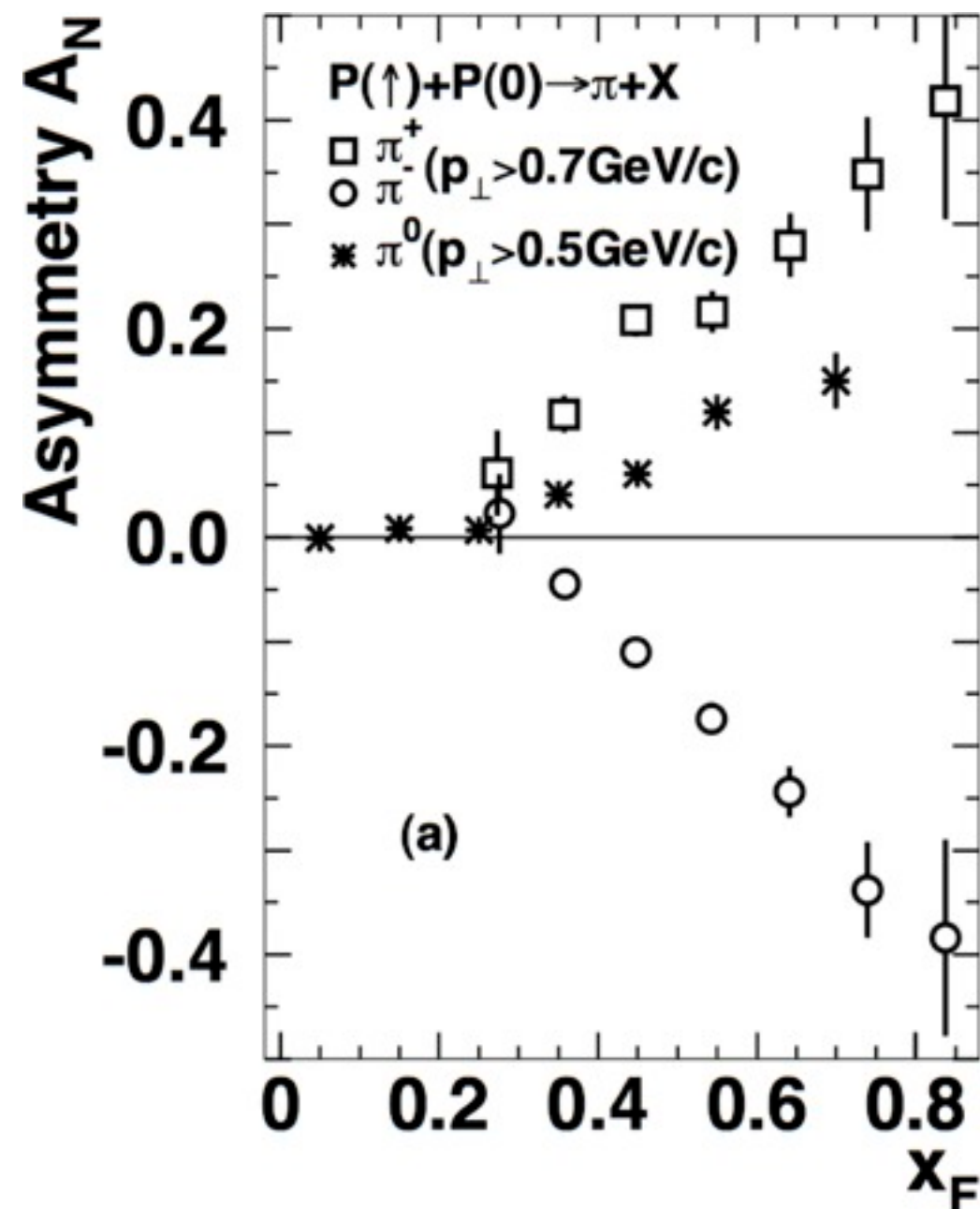
eRHIC projections for:

- 10 + 250 GeV
- 9fb^{-1}

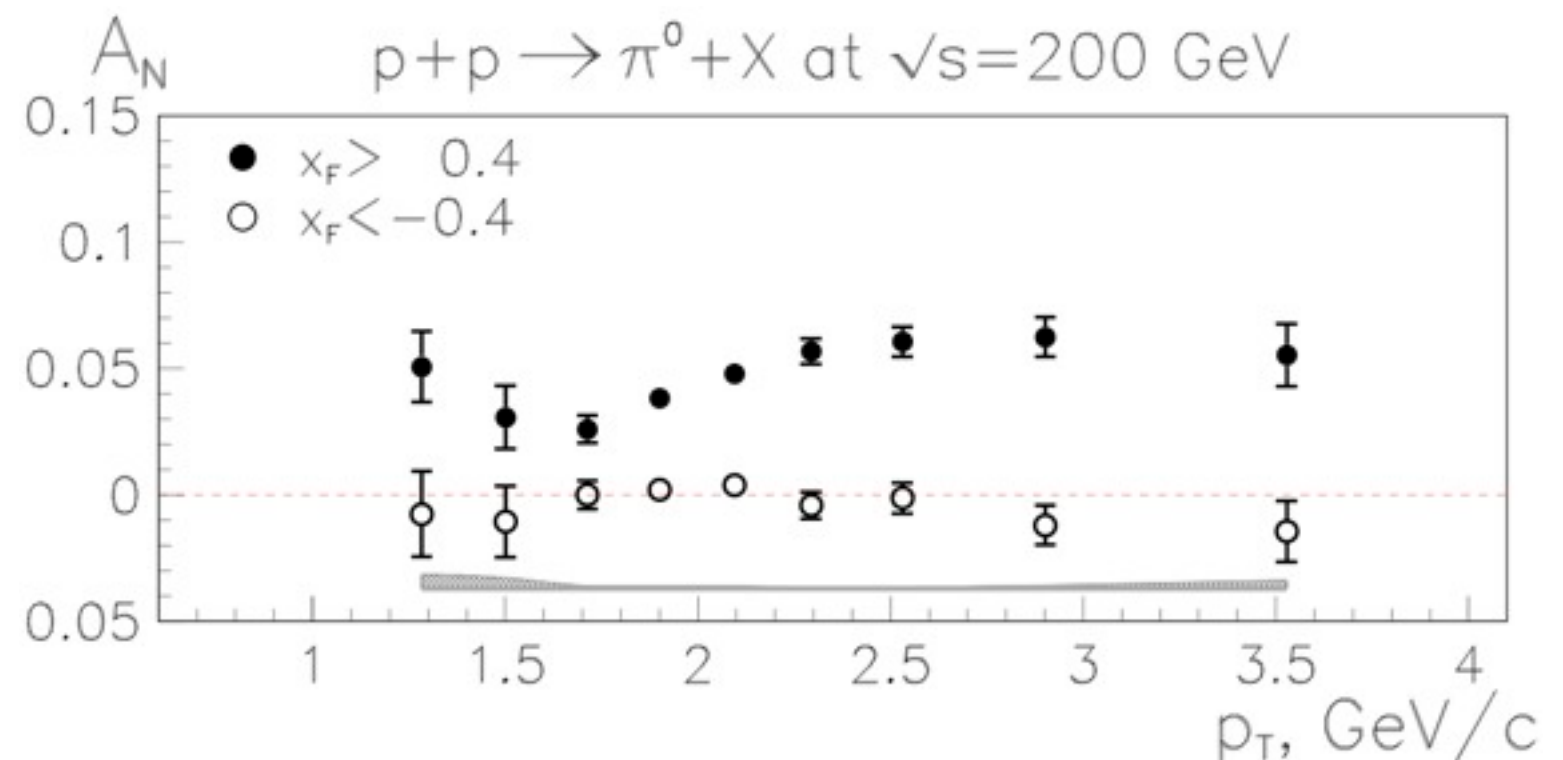


Transverse spin

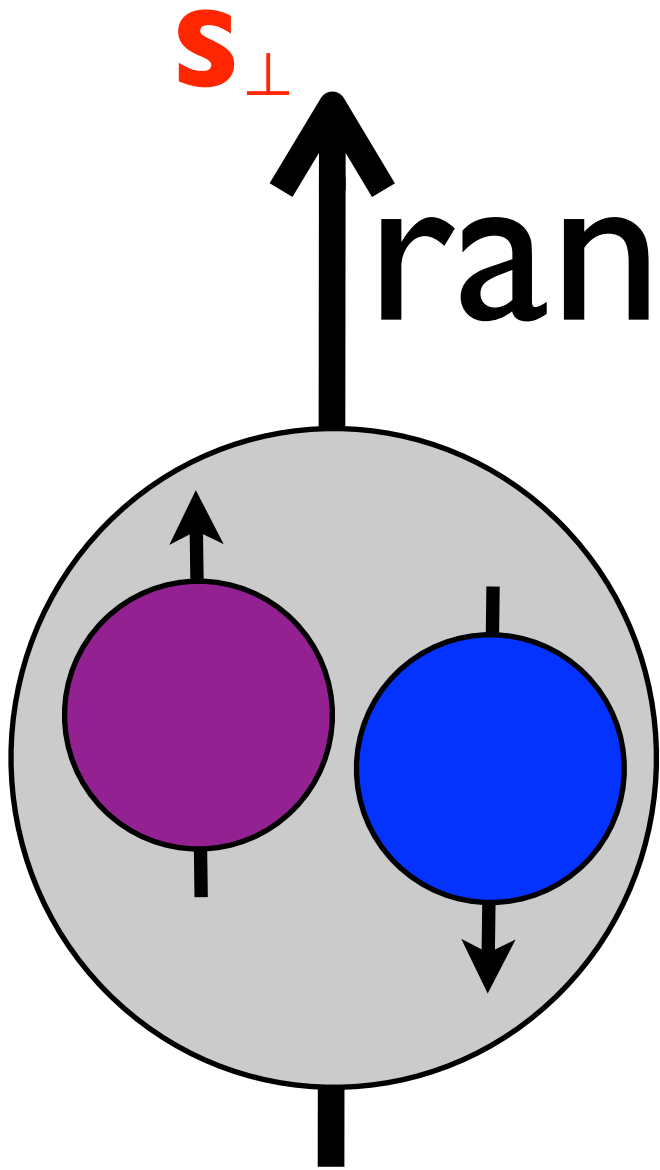
Transverse spin asymmetries



- First seen in $p + p$
- What is their origin?



transverse spin topics



Transversity distribution $\delta q = q\uparrow - q\downarrow$

“Collins” fragmentation functions

Fragmentation depends on S_\perp

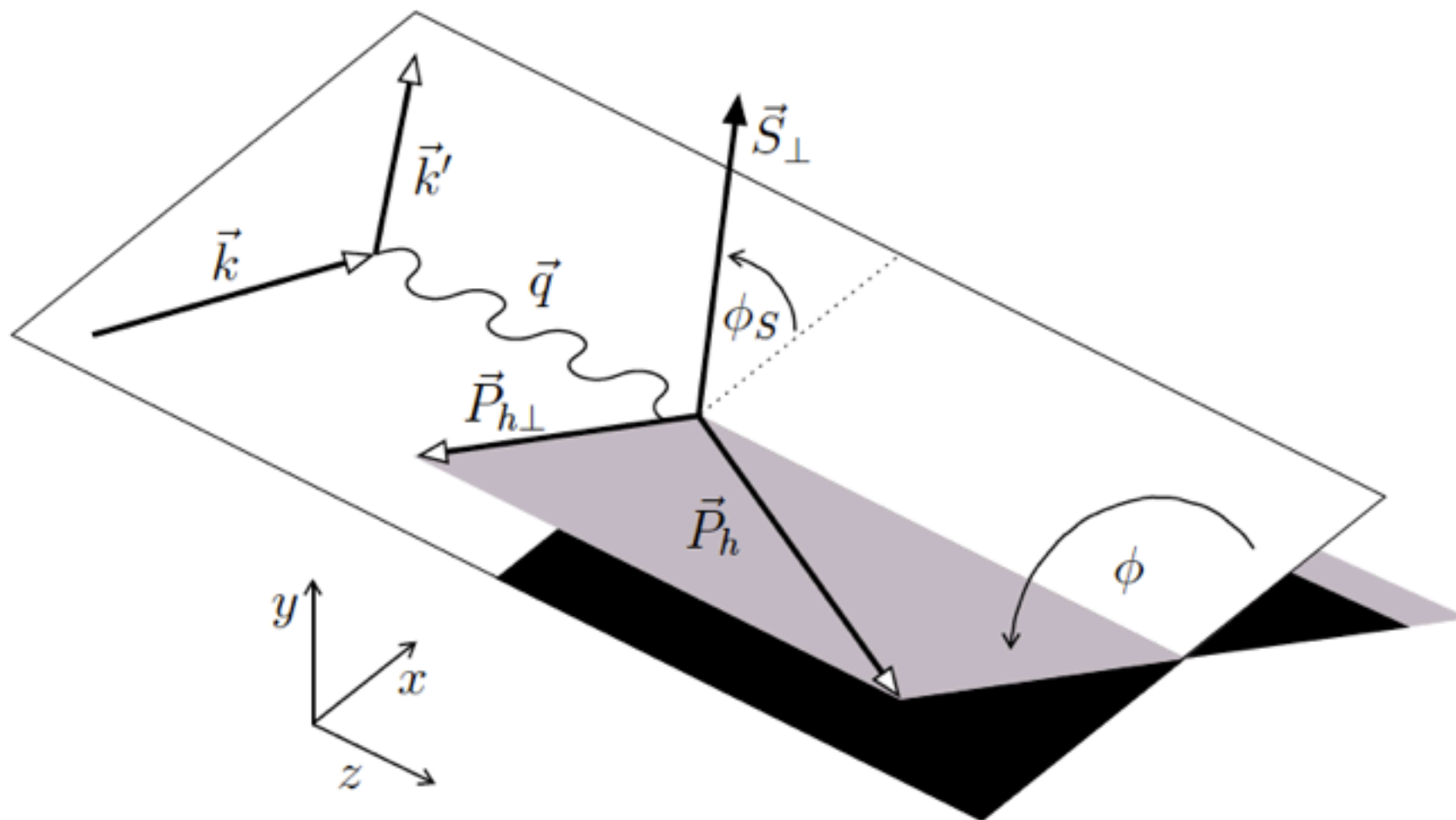
Transverse-
momentum-
dependent
functions
(TMDs)

“Sivers” parton distributions

Parton distributions depend on S_\perp

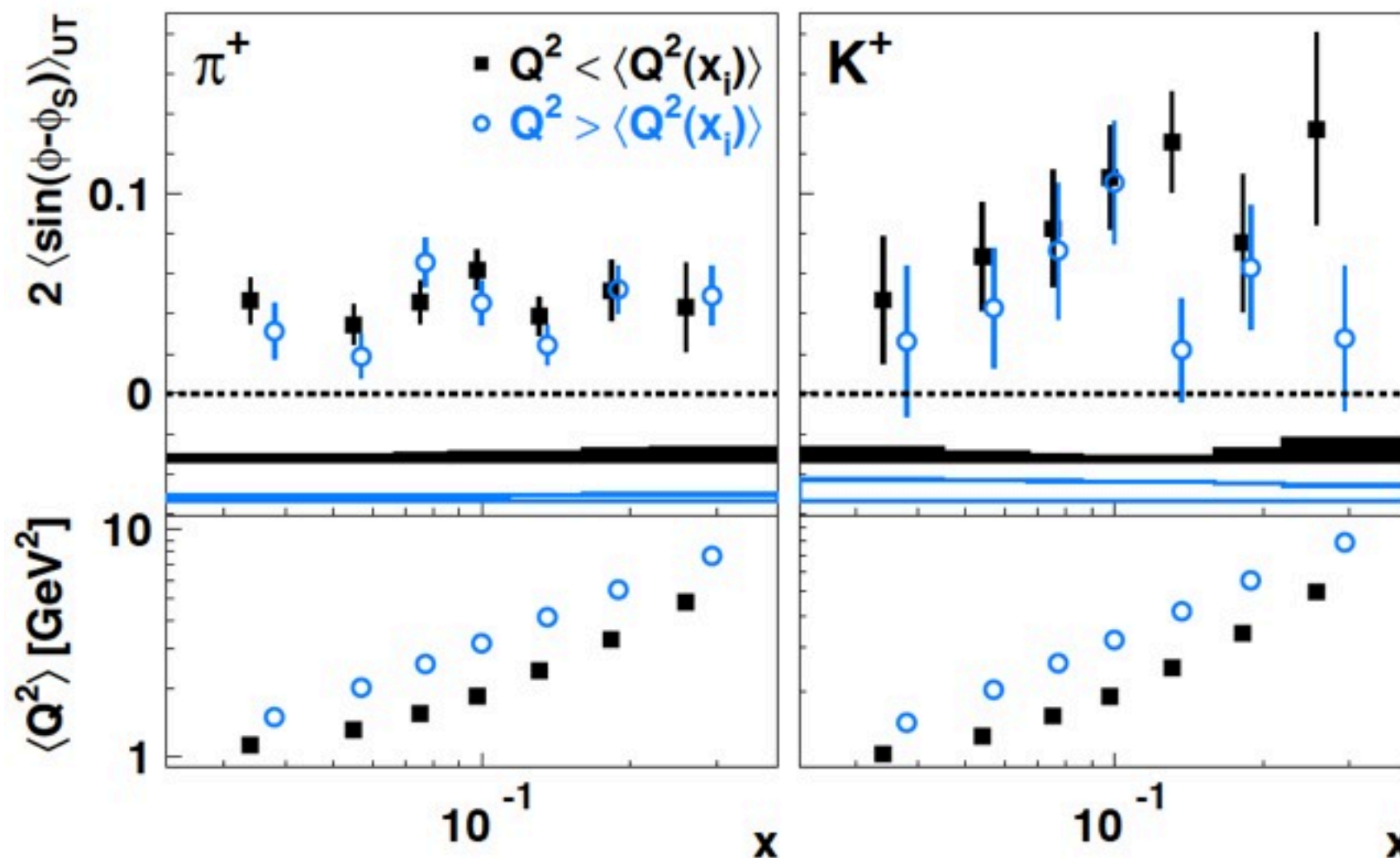
Transverse spin in SIDIS

- Collins & Sivers - different azimuthal dependence
- ➡ Disentangle the effects



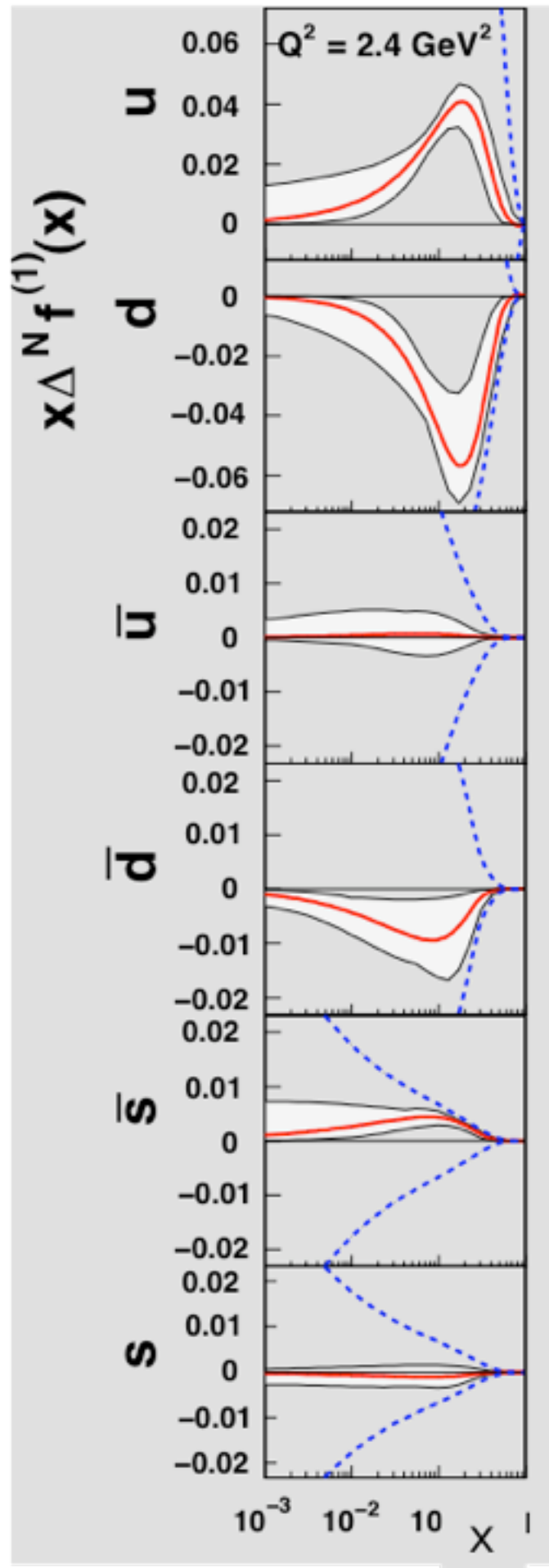
Transverse spin in SIDIS

- Collins & Sivers - different azimuthal dependence
- ➔ Disentangle the effects



Phys. Rev. Lett.
103 (2009)
152002

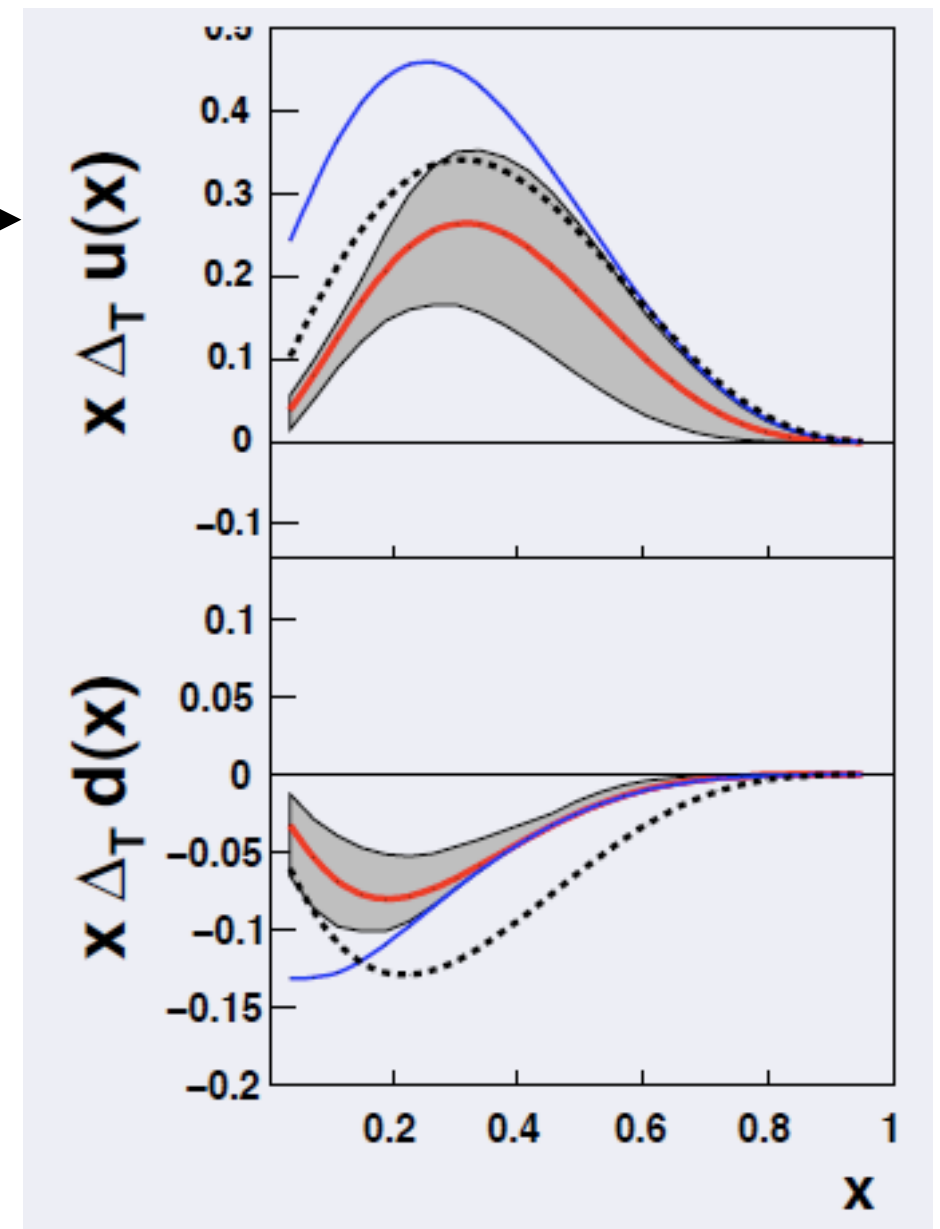
Current status



Transversity →

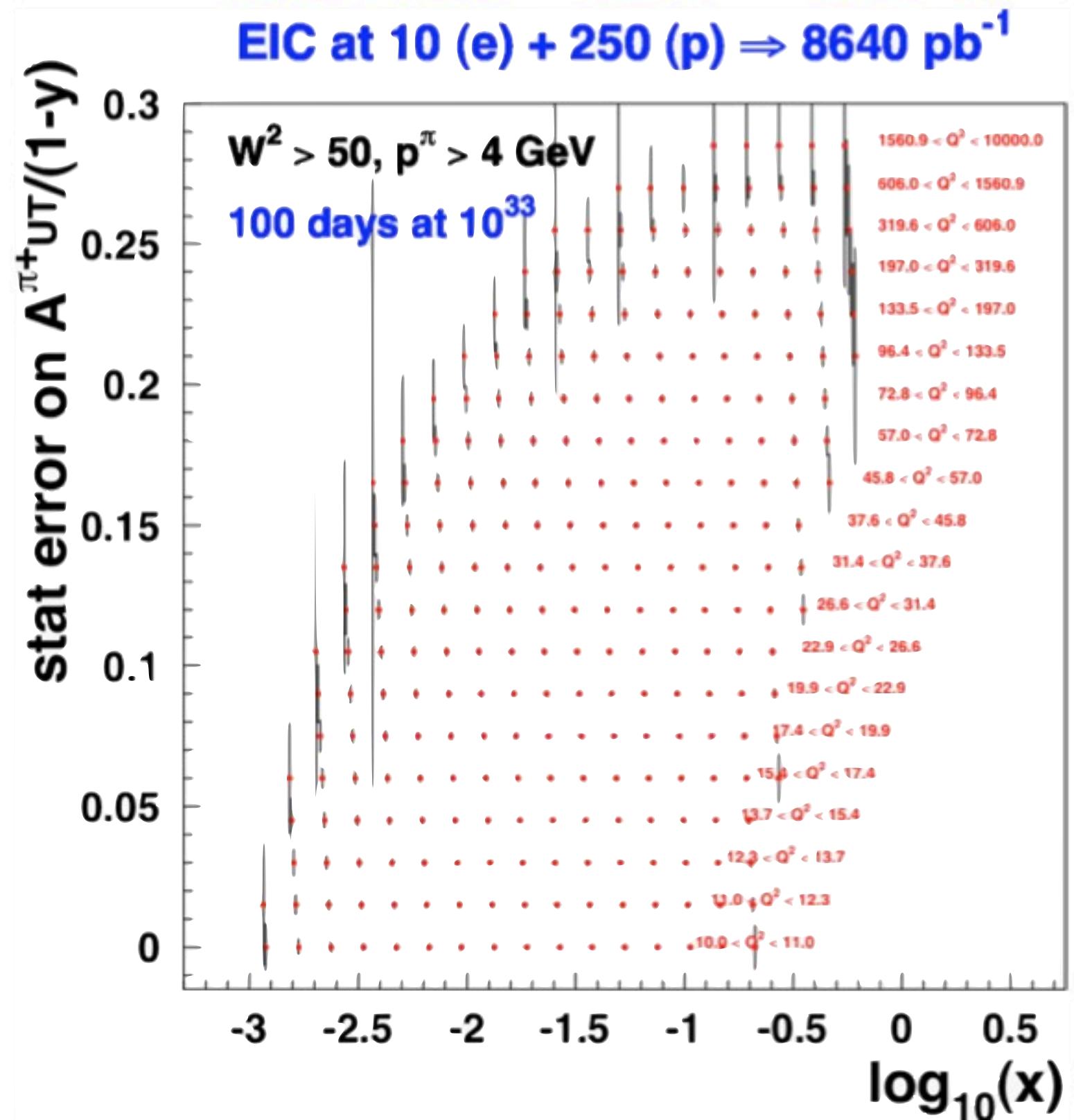
Uncertainties remain large

← Sivers functions



Sivers at EIC

- High luminosity
- ➔ x , Q^2 & momentum dependence
- ➔ multi-dimensional binning



Transverse spin at EIC

- Uncertainties remain large compared to helicity distributions
- Precision measurements of TMDs, including their momentum and Q^2 dependence
 - Sivers, Collins, Boer-Mulders...
- Precise measure of transversity
- High energy \rightarrow theoretically interpretable

EIC summary

- Complementary x , Q^2 , energy range to past & existing experiments
- High luminosity → precise
- ➔ *Will advance our knowledge of all aspects of the spin puzzle*
- Also see talks by:
 - Elke: GPDs
 - Thomas Ullrich: EIC physics case
 - Vladimir: eRHIC machine design